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A Hazard Detection Sensor for Landing on Europa

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Europa Lander Mission Concept

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Co-Authors

- From Europa Lander Concept team
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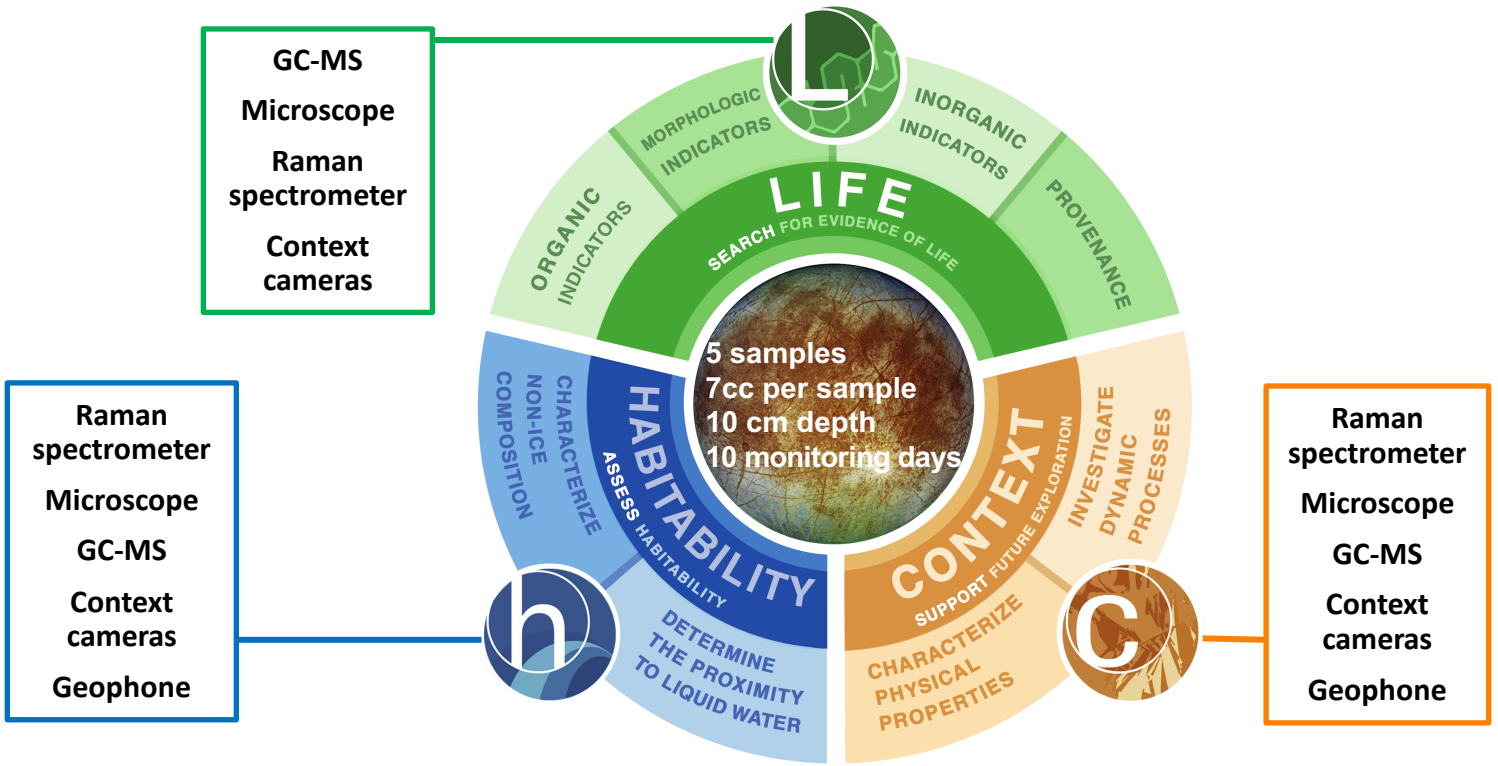
Science Definition Team Recommendations

A connected set of goals and objectives addressed with a focused model payload



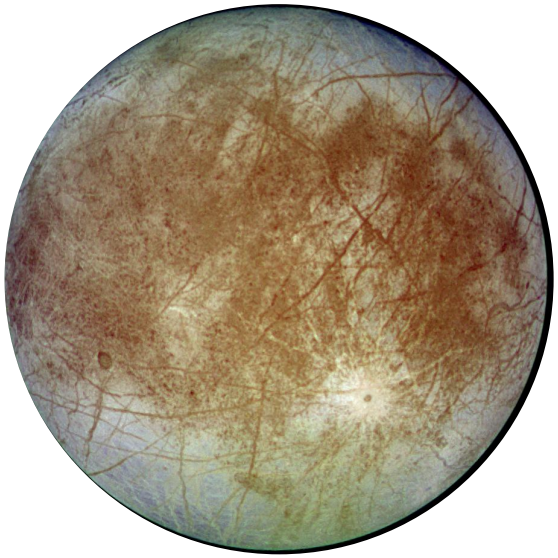
Scientifically interesting Locations on Europa are Likely to Have More Challenging Topography

Challenges of Landing in Europa

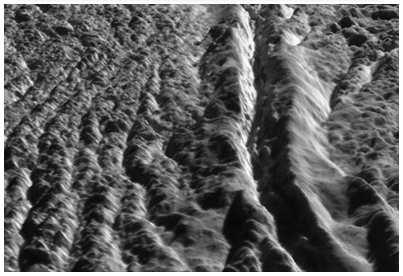
Current Lack of High-res Recon Maps

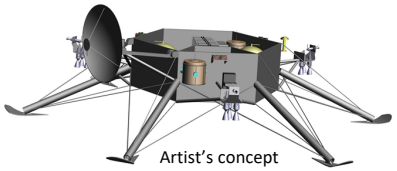
Highest Resolution Europa image currently available

Illumination Variability



Highly Hazardous & Unknown Terrain

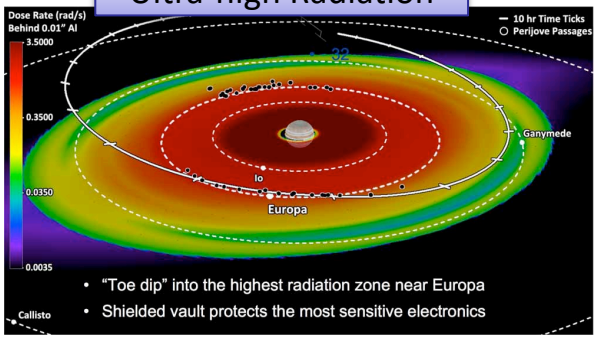


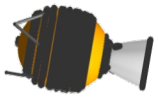


Artist's concept

Limited Lander SWAP Resources

Ultra-high Radiation



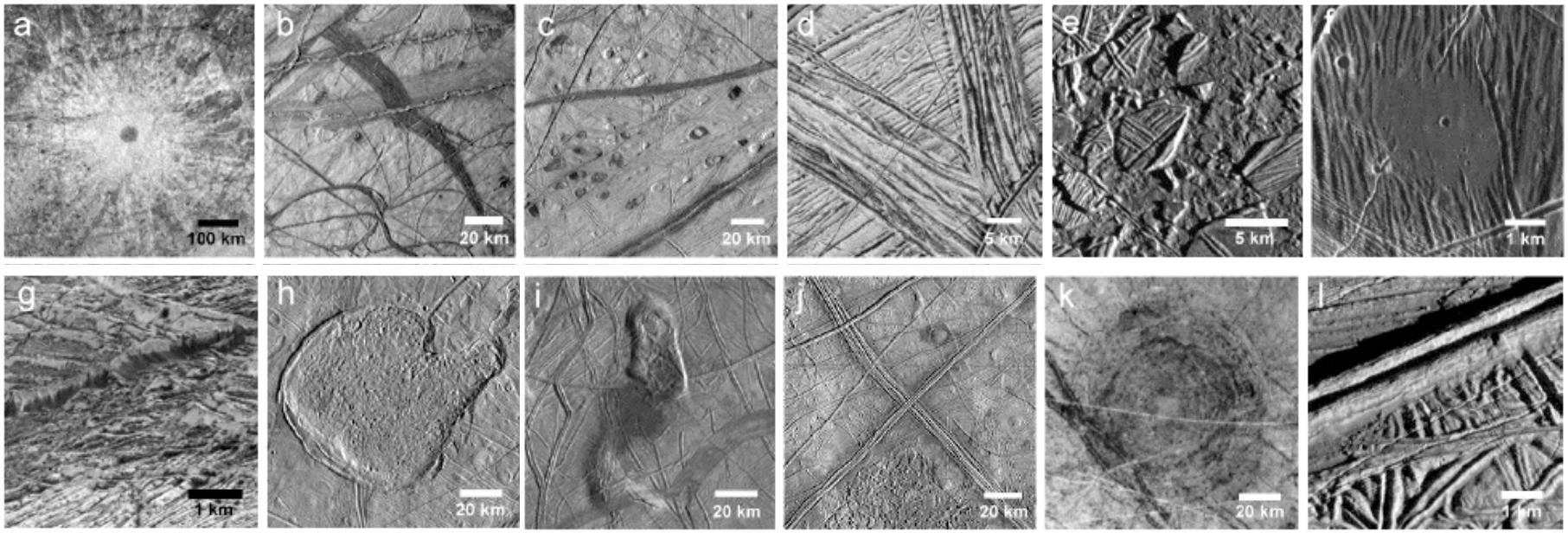


Large Propulsive Delta-V

Less than 10^{-4} probability of introducing a single "Viable Organism" to any Europa habitable zones

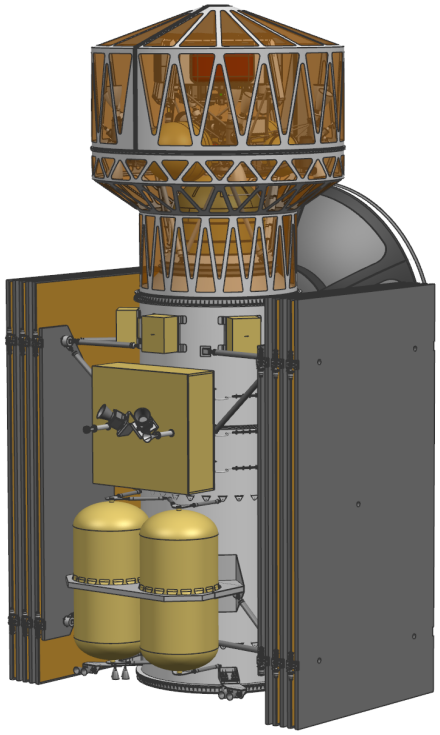
Planetary Protection

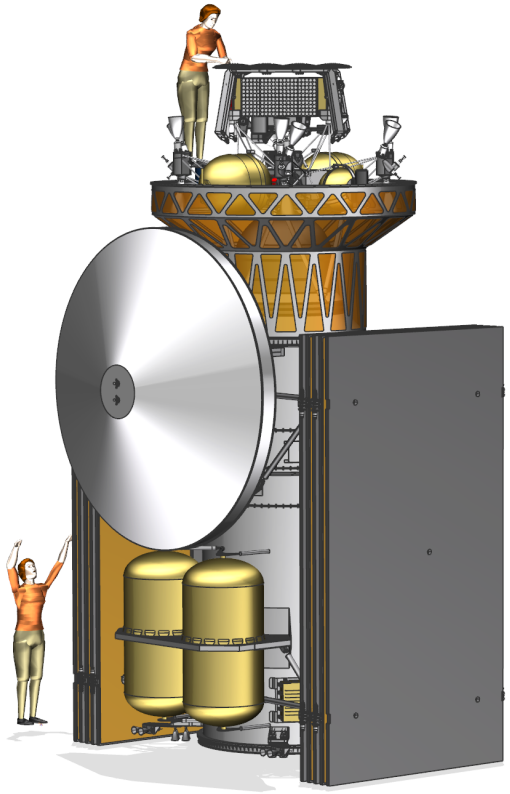
Galileo Images Show Europa Having Rugged, Unusual Terrain



Penitentes

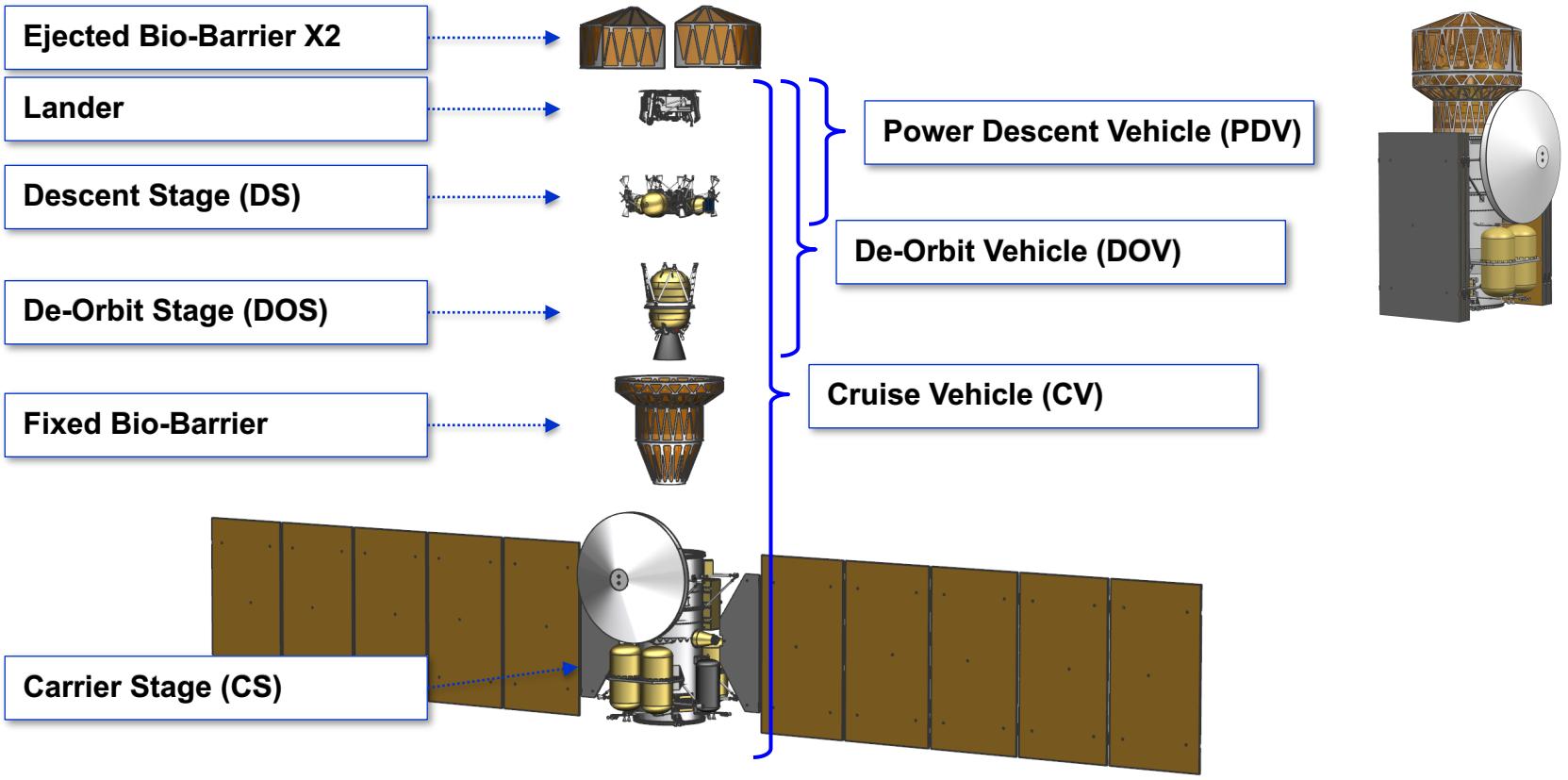
Launch Stack Is About Three Stories Tall





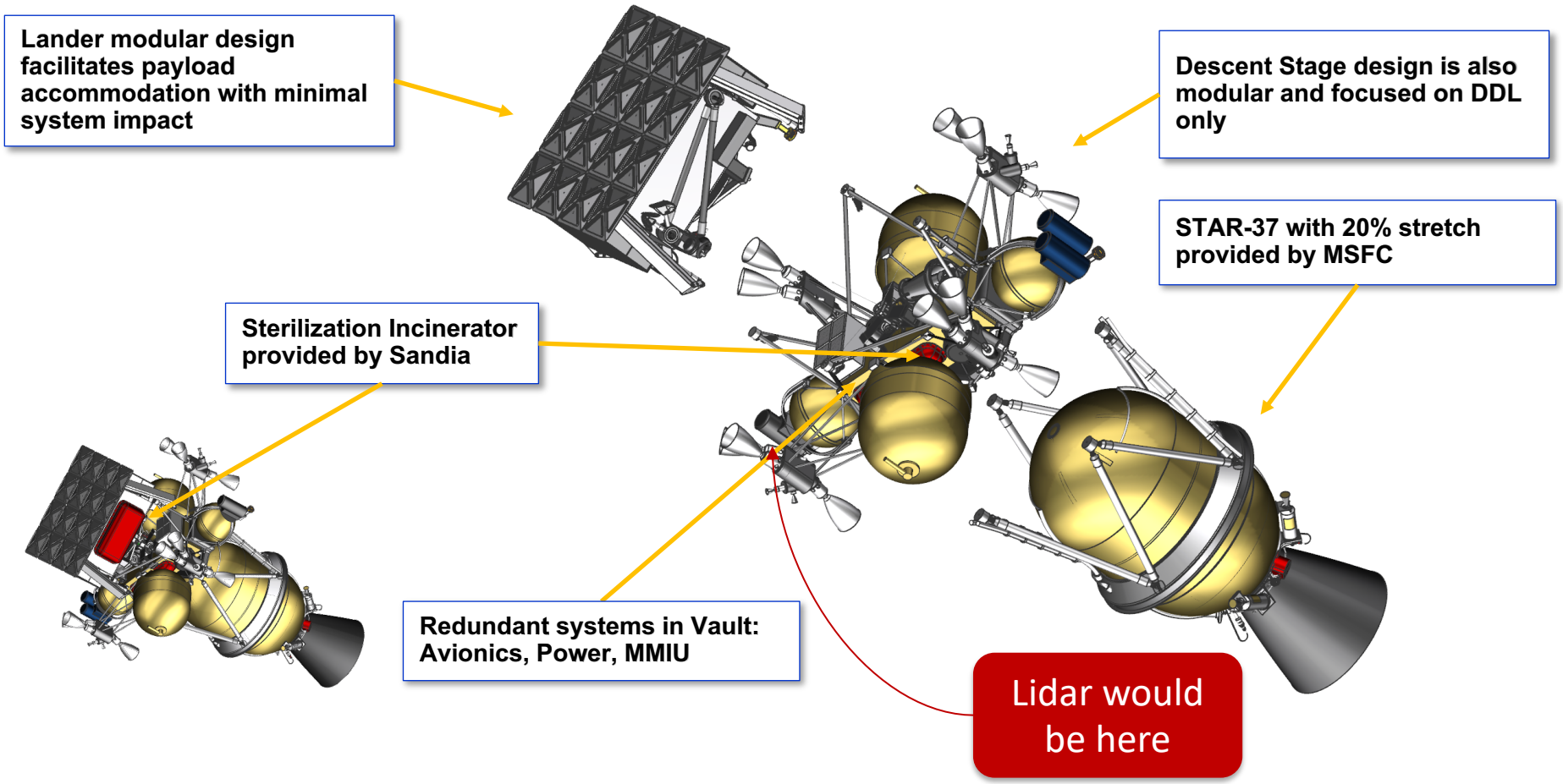
Artist's concept

Flight System Launch Assembly & Nomenclature



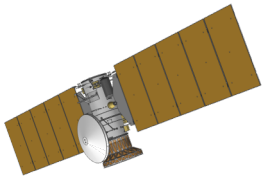
Artist's concept

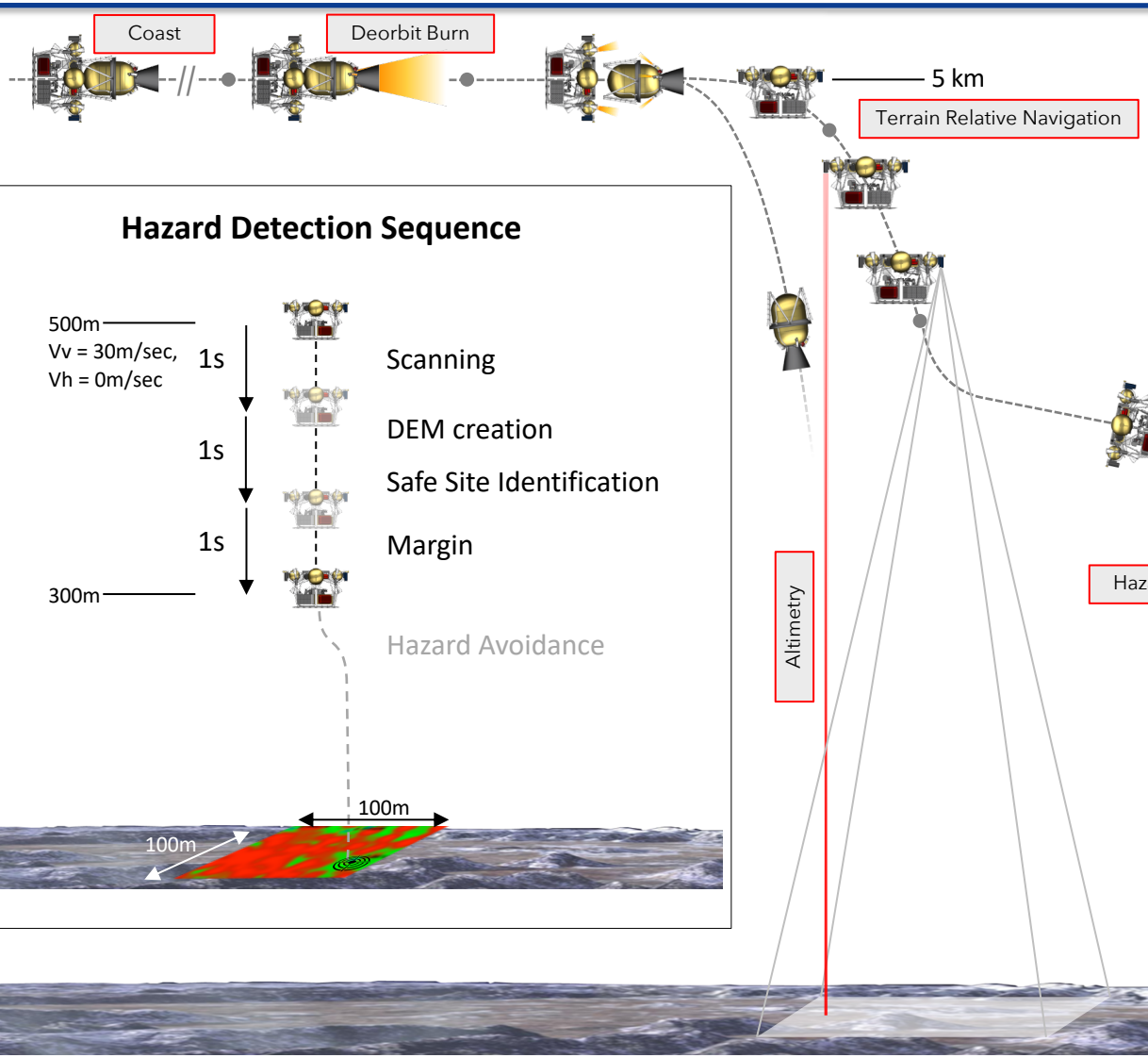
De-Orbit Vehicle Has a Modular Concept



Artist's concept

DDL ConOps





Hazard Detection Sequence

Hazard Mapping Requirements

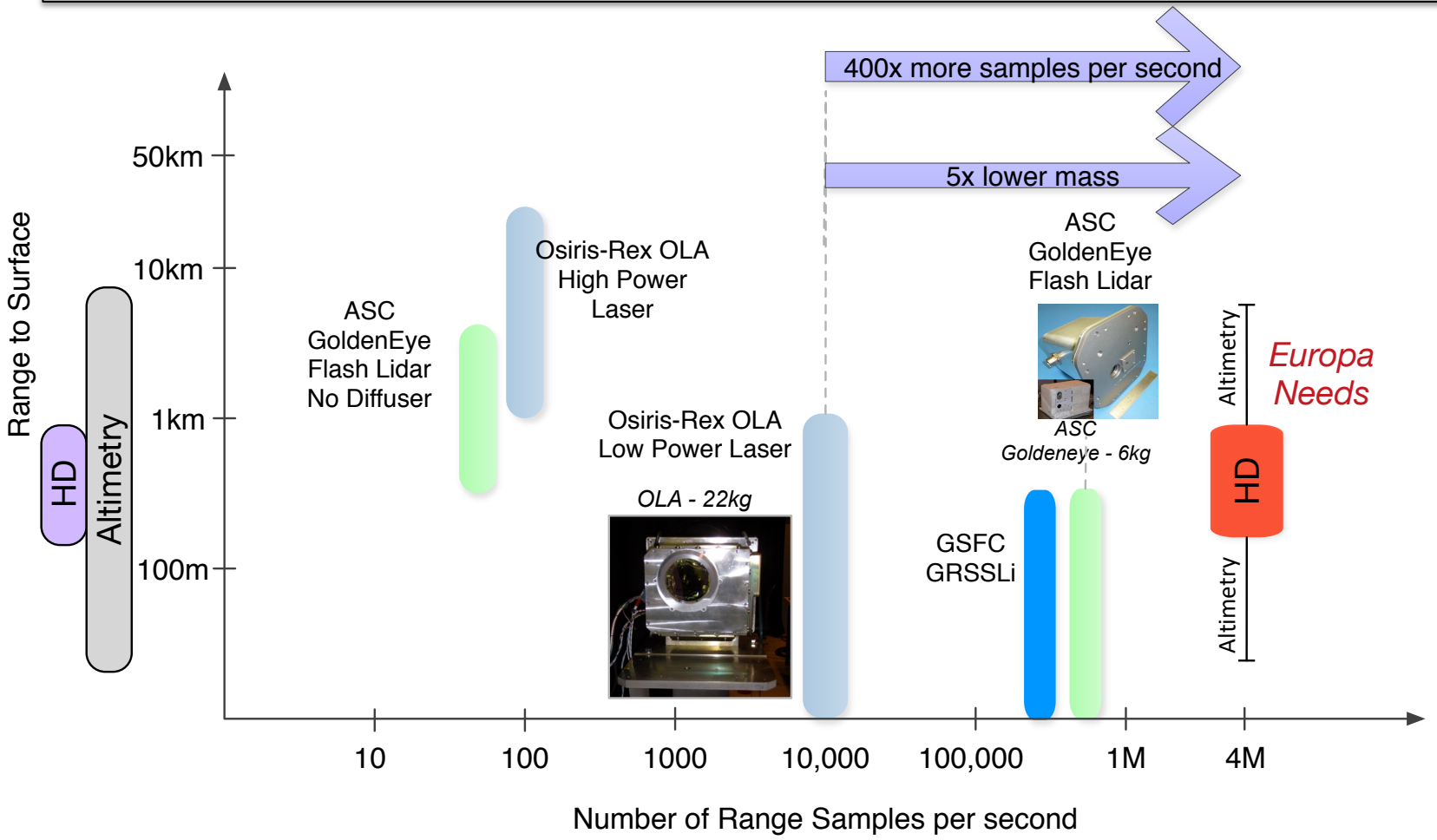
- 50m divert capability
  → 100m x 100m search area
- 100m x 100m map at 5cm resolution
  → 4MPixel DEM
- 1s scan time
  → at least 4MPixel/s sensor measurement rate

LIDAR Requirements

- DEM Generation
  - 100m x 100m
  - 5cm grid spacing
  - 5cm (3 sigma) elevation error
  - < 2 sec data acquisition and DEM generation time
- True Trajectory
  - Altitude = [400-500]m
  - Constant vertical velocity V_v = 30 m/s, +/- [0.4-0.7] m/s
  - Zero horizontal velocity V_h = 0 m/s, +/- [0.4-0.7] m/s
  - Nadir-pointed attitude, +/- 0.1 deg change over 2 s
- Estimated Trajectory
  - Velocity knowledge error = [0.3-0.6] m/s (3 sigma) per axis, constant through acquisition
- Mass (including shielding) < 7kg
- Power < 50w
- Volume < 25cm x 25cm x 25cm (optical head, electronics box, each)
- Radiation TID
  - 1.7Mrad (Si) behind 100mil of aluminum
  - 300 Krad (Si) inside electronic vault (RDF = 2)

Comparisons with State-of-the-Art

Existing LIDAR sensors cannot meet performance requirements for Europa and survive in the extreme radiation environment



Preliminary Studies and Background

- ConOps and LIDAR requirements developed based on ALHAT experience
- Technical management of SBIR's for space HD applications
- Issued Europa Lander detector array study contracts
  - Feasibility
  - Radiation susceptibility
  - Detector architecture
  - LIDAR architecture
- Issued Sensor RFI
- Issued RFP

Trade Space

- Detection
  - Coherent vs. incoherent
  - CW vs. Pulsed
  - Linear Mode
  - Single Photo Detection
  - Geiger Mode
- Frame Acquisition
  - Flash LIDAR
  - Scanning single detector
  - Scanning array of detectors
    - Size and shape of detector array
- Scanning approach
  - Galvo mirrors
  - Polygonal mirrors
  - Fast Steering Mirrors
  - Risley prisms
  - Solid state
  - MEMS
- Overall Architecture
  - Separate altimeter vs. combined altimeter/HD
  - Separate optical head vs. single integrated box

Sensor Development Approach (part 1)

- Objective: TRL 6 by Europa Lander PDR (2021)
  - Prove that the Design meets performance requirement in the relevant flight-envelope (altitude, velocity, angular rates, terrain, etc.)
    - Field Tests with Brass-board
  - Prove that the Design can be space qualified
    - Parts lists analysis
    - Component radiation testing
    - Radiation Test Unit for testing by JPL
  - Prove that the resulting Flight Model will meet SWaP requirements
    - Preliminary detailed design for EM and FU
  - Prove that the Flight Unit can be developed within project costs and schedule constraints
    - Development team including partners and component vendors
    - Preliminary cost and schedule plans

Note: Brass-board must be relevant relative to its function: test sensor performance in a realistic flight-envelope

Sensor Development Approach (part 2)

- Approach:
  - Select two teams to develop two TRL-6 designs with the following deliverables
    - Detailed design description and performance analysis
    - Fieldable Brass-board
    - Radiation Test Unit
    - Parts analysis and selection
    - Radiation testing of critical components
    - Preliminary detailed design for EM and FU
    - Preliminary cost and schedule for EM and FU
  - 3-Phase development with 2 gates for down-selection and/or termination
    - Phase 1: Systems Engineering & Trade Studies
    - Phase 2: Detailed Design
    - Phase 3: Build & Test Brass-board

Sensor Development Approach (part 2)

- Status:
  - Three vendors selected for Phase 1
    - Sigma Space
      - Commercial vendor with experience in aerial terrain mapping and LIDAR for space, selected competitively after issuing RFP
    - MIT Lincoln Labs
      - FFRDC specialized in Geiger Mode LIDAR
    - Goddard Space Flight Center (GSFC)
      - NASA center with experience in altimetry for space applications (MOLA, LOLA, etc.)
  - Phase 1 almost complete

Conclusions

- The Europa Lander Study is developing a Hazard Detection LIDAR sensor that represents a significant jump in sensor performance and SWaP while meeting the harsh radiation European environment
- A careful sensor development strategy was developed based on previous experiences
- Three vendors have been selected with designs that span a large architectural space